

Concepts and Recommendations for Using the “Natural Conditions” Provisions of the Idaho Water Quality Standards



Cover: Shoshone Creek near the Idaho/Nevada border, by Mike Edmondson IDEQ (top); Middle Fork of the Salmon River below Wilson Creek, by Don Essig, IDEQ (bottom left); and the confluence of Robin Creek with Lochsa River, by Chris Mebane, IDEQ (bottom right).

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([Blue text](#) indicates hyperlinks to regulatory definitions or other internal links)

Introduction

Natural conditions and natural variability are considerations throughout Idaho's water quality standards. The issue is particularly fundamental to attempts to evaluate and manage temperature in streams and rivers, siltation or accelerated erosion in watersheds, and nutrient increases and cultural eutrophication of rivers, lakes and reservoirs. The following is a discussion of some of the concepts, complexities, and applications of natural conditions provisions of Idaho's water quality standards.

The purpose of this discussion paper is to 1) describe some of the needs and complications involved in regulating naturally occurring conditions in waters, 2) provide some practical advice for implementing natural conditions provisions of the Idaho water quality standards, and 3) compile all provisions of Idaho's water quality standards relating to natural background conditions.

Aquatic ecosystems are usually influenced by a combination of natural and anthropogenic factors. In order to effectively limit pollution and manage water quality, some understanding of these combined influences are necessary. If ecosystems are limited by natural factors, efforts to remedy or control these factors will be misguided and ineffectual. To justify expensive controls, environmental managers need to predict with reasonable certainty that the outcome of required remediation or control measures will be an improvement in the environmental properties of concern. Separating the effects of natural factors from anthropogenic factors is difficult and requires an understanding of, and some ability to quantify the influence of each (Baird and Burton 2001).

Environmental pollutants can be thought of in two categories – 1) human-created substances that would not even naturally exist in the environment, or at least not naturally be widely distributed in the environment, and 2) naturally-occurring substances or conditions that can be altered by human activities in ways that are environmentally harmful. Examples of the first category include synthetic organic chemicals such as pesticides, PCBs, and byproducts of petroleum refining or combustion. Setting standards for these substances is not complicated by having to factor out naturally occurring levels. For example the naturally occurring concentration of synthetic chemicals such as the pesticides diazanon or chlorpyrifos, is zero, and zero amount is biologically essential for life. Because the concentrations of such substances is not complicated by natural background, setting environmental standards can be based on their fate and effects in the environment, usually with some consideration of costs and benefits. However, setting environmental standards for substances and conditions that naturally occur, are naturally variable, and are biologically essential to life, but can be harmful when concentrated or altered is additionally complicated.

The second category includes elements that make up the Earth's crust and are naturally present in soils and waters in concentrations roughly proportional to their crustal abundance. Iron, zinc, selenium, copper, cobalt and phosphorus are examples of naturally occurring elements that are essential to life, but can become toxic in excess amounts. Sediment, nutrients, and temperature are additional inherent, essential, and variable features of a stream environment. If human-activities significantly alter these features, aquatic environments can be harmed. Yet, because these features are naturally

variable, at times and in places aquatic environments can be naturally unsuited for many aquatic species for two fundamental causes: natural disturbances and limits of range. Disturbances like natural windstorms, forest fires, volcanic eruptions, landslides, floods or drought can all change stream habitats in ways that are harmful or completely unsuitable for fish. Particularly in the case of temperature, natural limitations often determine the very geographic range of aquatic species. It is a statement of the obvious that fish such as trout that naturally thrive in northern latitudes or high elevations, will not persist in sub-tropical Florida and conversely warmwater fish such as gars or cichlids will not persist in cold temperate conditions. However, at the margins of their ranges, these natural limitations are less obvious. At the margins of their ranges, natural limitation is most operative, and it is there that sorting out natural versus man-caused effects is most important as well as most complicated. For example in much of the West, trout only occur in mountain streams; as streams lose elevation and warm, there is a natural transition of the fish assemblage as trout are replaced by minnow and sucker species that are more tolerant of warm water. However, continua or naturally shifting gradations in conditions are not handled easily in Idaho's water quality standards. Instead, designated uses and their associated water quality criteria usually are applied to discrete places and times, with the locations different aquatic life use designations such as salmonid spawning, coldwater, or seasonal-coldwater aquatic life and neatly shown on maps. Constantly variable continua of conditions cannot be mapped so neatly. Natural conditions provisions are an attempt to acknowledge and lessen this disjunction between nature and environmental regulation.

The problem of distinguishing natural transitions becomes important because the effects of human disturbances can be to move this natural transition zone further upstream (e.g. Rahel et al. 1991). Yet, should water quality managers attempt to remediate naturally occurring conditions, they will not succeed, will waste time and money, and will undoubtedly lose the good will of affected people asked to improve upon natural conditions. Hence, a challenge for water quality managers when evaluating a stream that, for example, is warmer than biologically based criteria that are protective of fish, is to make reasonable estimates of what proportion of the streams temperature is due to natural conditions, and what additional increment is due to human alterations, such as the removal of shade, or changing the shape of the channel to be wider and shallow than natural. This becomes especially challenging since natural variability often makes potentially harmful human alteration difficult to detect. Unless alterations were very large, multiple years of monitoring could be required for statistically significant trends to be detected. Further, aquatic systems could probably be intensively studied indefinitely without ever fully understanding their natural dynamics (NRC 1990).

Hence, a practical need of water quality analysts and policy makers is how to strike a balance between the risks of allowing undetected degradation, requiring misguided remediation, or causing analysis-paralysis where valuable time and money is spent on analyses that are excessive or inconclusive? In situations where a prospective disturbance in a mostly natural watershed is irreversible or nearly so, then analyses should be rigorous. Examples could include proposals for major construction projects such as a new large, open pit mine, a major highway expansion, or a major new ski resort. In lower risk situations where actions can be readily adapted based on new information (adaptive management), or if actions could be iterative, such as how much

restoration is needed to restore aquatic life beneficial uses from past disturbances, rapid decision making to allow actions to begin may be more important than complete analyses in advance of actions.

The main goal of this discussion is to point out some general principles that may be used to estimate what natural background conditions are, and or, principles to estimate human-caused incremental increases. When streams naturally exceed temperatures or other conditions favorable to fish, further increases from human-activities need to be small.

This paper describes factors that we think should be considered in interpreting and applying water quality standards in relation to natural background conditions. Because situations where natural temperatures in streams and rivers exceed numeric criteria are ubiquitous, temperature is emphasized. For example, Ott and Maret (2003) studied the relationships between temperature regimes, biological, and habitat variables in natural streams in the Salmon River basin, Idaho. Study sites were in roadless areas or were at the limits of road access in carefully selected reference sites. 2001, the year sampled, was a near-average climatic and hydrologic year for the basin. 100% (33 of 33) of study sites exceeded one or more numeric temperature criteria. 100% of sites exceeded the EPA bull trout standard of 10°C maximum weekly maximum temperature (MWMT) and 91% exceeded the Idaho salmonid spawning criteria of 13°C daily maximum temperature or 9°C daily average temperatures during the core spawning periods for species encountered. In a larger study conducted during 2000, a warmer than average year, 100% (183 of 183 sites) of mostly natural sites in the Salmon and Clearwater basins exceeded the salmonid spawning criteria values at some point in the summer (Donato 2002).

Concepts to consider when evaluating whether natural background conditions exceed numeric criteria

We considered the following concepts to be fundamental when evaluating questions of natural background:

1. *Causation* – Water quality standards are intended to address *human-caused* exceedences of numeric or narrative criteria values; thus where both natural and anthropogenic factors cause exceedences of criteria values, anthropogenic sources need to be held responsible for that portion of the exceedence they cause.
2. *Acknowledgement of human habitation and uses* – When natural background conditions exceed any applicable water quality criteria, pollutant levels shall not exceed the natural background conditions, except that temperatures may be increased above natural background conditions by 0.3°C. The latter provision is based on the concept that human uses of natural resources in a watershed, or habitation in the watershed are not de facto prohibited by absolutist water quality standards. Even the most environmentally conscientious humans cannot magically float above the landscape without causing any changes, even with the best of management practices. Instead, the concept is that changes in water quality related to human activities should be small, protecting aquatic ecosystems, and human uses of waters.

3. *Watershed scale of assessment* – “Natural background conditions” are defined in Idaho’s water quality standards as “no measurable change in the physical, chemical, biological, or radiological conditions existing in a water body without human sources of pollution within the watershed.” Hence, *natural background should primarily be assessed on the watershed scale*. In this context, natural background is defined as no measurable change in the physical, chemical, or biological conditions existing in a water body without human sources of pollution *within* the [watershed](#). The intent of this definition is to exclude global or regional climatic changes from the scope of evaluations needed to assess “natural” water quality conditions. Global warming has been predicted to cause increased temperatures in streams and rivers, and as a result salmonid habitats are predicted to become unfavorable or to contract northward and to higher elevations (e.g. Kelleher and Rahel 1996, Petersen and Kitchell 2001). Global climatic changes cannot be controlled by point and nonpoint water pollution control measures available to water quality managers, land managers, dischargers, etc.. Thus, for the example of regulating stream temperatures through point and nonpoint pollution control measures in Idaho, prevailing climatic conditions are considered to be part of the “natural” background.
4. *No measurable change* – Because natural background conditions are defined as having “no measurable change in the physical, chemical, biological, or radiological conditions existing in a water body without human sources of pollution within the watershed” defining “measurable changes” is fundamental. As a working definition, “measurable changes” are considered to be changes that are significantly large to be capable of being measured using routinely available technology and a reasonable number of samples. In the case of temperature, modeling is frequently used to evaluate natural temperatures or “what if” scenarios. Strictly speaking, a *modeled* change is not a *measured* change. However, since stream temperature models are a necessary and well tested means of evaluating temperature regimes and changes, it is the *magnitude* of change that the measurability test should be applied to, not whether the change was predicted by modeling or measured in the field. For example, an appropriately modeled 2°C increase in average July stream temperatures would likely be of greater concern than a measured 0.2°C increase. Whether the *magnitude* of change in the physical (e.g. temperature), chemical (e.g. metals), or biological conditions (e.g. biological metrics) of a waterbody is detectable depends upon the capabilities of the measuring instrument or method, the variability of the system, and the sampling effort. This is discussed in more depth later in the section on [Measurable Change](#).
5. *Maintenance of high quality waters* – Idaho’s [antidegradation policy](#) states that “where the quality of the waters exceeds levels necessary to support propagation of fish, shellfish and wildlife and recreation in and on the water, that quality shall be maintained and protected....”¹ This policy is complementary to the natural conditions

¹ On a case-by-case basis, DEQ may allow lower water quality if it is necessary to accommodate important economic or social development. If lower water quality is allowed, existing aquatic life uses and water-quality suitable for recreation must still be fully protected, and comprehensive point and nonpoint source controls must be used. Public participation is required prior to allowing lower water quality. See WQS § 051 and 003.58 (appended).

narrative standard. In the antidegradation context, we interpret “quality” to be maintained when there is no lowering of water quality. Lower water quality is defined as a “measurable adverse change in a chemical, physical, or biological parameter of a beneficial use, and which can be expressed numerically.” Further for temperature, allowable increases due to [thermal discharges](#) are specifically limited to 1.0°C for waters designated for cold water aquatic life. We interpret this allowance as a presumption that so long as stream temperatures are still lower than applicable numeric limits, a 1.0°C increase would not likely be adverse to aquatic life uses of the stream. If there we evidence that such an increase would likely be adverse, more [stringent](#) limitations could be imposed.

Thus if natural stream temperatures were naturally cooler than numeric criteria, then the temperatures would not be allowed to increase up to the numeric criteria. For example, if the criterion for a natural stream were a daily average of less than 19°C, and the highest measured daily average was 15°C, new or increased temperature sources would be limited to causing an increase of 1.0°C at the edge of the mixing zone, for a 16°C maximum daily average. An increase of 4.0°C, to the 19°C daily average criterion would not be allowable.

6. *“Natural” is a relative, rather than an absolute concept.* “Natural” in the present context is considered to be the most-natural conditions available for comparison to the water body of interest. For example, [reference conditions](#) are considered to be “natural conditions with few impacts from human activities and which are representative of the highest level of support attainable in the basin.”
7. *Does “natural” exclude humans?* The extent to which definitions of “natural” conditions include people is the subject of debate (e.g. Landres et al 1999, Mann 2002, Soulé 2002). Since immigrating to North America, humans have likely been an ecologically significant species for at least the last 11,000 years or so. These Pleistocene immigrants likely contributed to the extinctions of most large, grazing mammal species in North America, the removal of which in turn may have changed upland and riparian plant associations. Deliberate, i.e. “prescribed burning” of forests and plains apparently maintained a more open forest canopy, with less undergrowth than would otherwise occur, and may have managed grasslands for better grazing or against forest encroachment (Barrett and Arno 1982; Denevan 1992; Flores 2001). More fundamental human-caused hydrologic changes to watersheds, such as reservoir construction and major flow diversions, flood control, channelization, the impervious areas of large cities, the conversion of some entire ecoregions to cultivated croplands only occurred in North America in the last 100-150 years. So streams and rivers significantly influenced by the latter types of activities cannot be considered “natural” conditions; yet some degree of land management pre-dates Euro-American settlement and should probably be considered natural by contemporary standards.

Suter (2003) argued that the goal of restoring pre-Columbian conditions in rivers using modern reference sites was ill-defined. He questioned whether practitioners of biological assessments “...*really believe that there was a particular pre-Columbian state, and what could that mean? Does it refer to conditions when the flood-plain*

was planted with corn and other crops by indigenous peoples, when the watershed had just been burned by pre-agricultural indigenous peoples to increase ungulate harvests, or before any humans when the landscape was shaped by megafauna including smasher-browsers?” His questions provoke similar questions for contemporary definitions of “natural conditions.”

8. *Euro-American settlement was concurrent with climate change* – Comparing present environmental conditions to pre- Euro-American settlement conditions may further be confounded by climatic differences at the times of the early written records, such as the Lewis and Clark explorations and other descriptions through the mid 1800s. The historical time period often associated with the classic American natural wilderness of 1550 – 1850 was in fact a time of climate anomaly, the Little Ice Age. The wetter and cooler conditions of the Little Ice Age resulted in more lush vegetation in the Great Plains and Rocky Mountains than typical of the periods before and since (Flores 2001). For example, in alpine areas of the central Rocky Mountains, analyses of glacial ice cores showed evidence of rapid and substantial warming. Since the end of the Little Ice Age to the early 1990s, increases in average air temperatures of ~5°C occurred in the alpine areas of NW Wyoming. About 3.5°C of that change in average air temperatures occurred recently, from the mid 1960s to the early 1990s. Air temperatures in alpine areas of the Rocky Mountains and other high altitude or high latitude sites may be increasing more rapidly than the global average during the 20th century (Naftz et al. 2002). This could confound or at least greatly complicate comparisons of current landscape conditions to early written records in the North American west.
9. *Natural ≠ Pristine* – Therefore, in order to evaluate “natural conditions” in contemporary water quality management, watersheds that are relatively unaffected by people are considered natural, e.g. wilderness and roadless areas. The past or present presence in a *watershed* of some livestock grazing, some forest harvest, and the occasional road crossings, do not necessarily preclude the *water bodies* from being outside the realm of “natural” conditions². It is the conditions in the *water bodies* that cannot be measurably changed by human sources of pollution. It follows that “natural conditions” in a watershed are not equivalent to “pristine conditions.” “Natural conditions” is a relative concept that includes some human-influences, but excludes watersheds with pervasive hydrologic or riparian changes. “Pristine conditions” meaning a landscape unaffected by humans, may be a term best reserved to describe some irretrievable Pleistocene past, or dropped from contemporary usage in environmental management since it is so problematic (Denevan 1992).

² Some reviewers of an earlier version of this paper found the use of qualitative words like “some” and “few” frustrating and asked for more definite statements for when a “few” impacts were a few too many for a stream to be *a priori* considered “natural.” For example, could screening checklists of potential impacts be included, such as no more than 2.0 miles of road per sq. mile, 0.25 road crossing per stream mile, 100 AUM, 15% equivalent clearcut area, etc.? While a few specific guidelines are included where they seemed justifiable, most of this overview is necessarily qualitative. In the future, developing additional screening thresholds for watershed-disturbance thresholds or natural stream features may well be feasible for different types of watersheds. Consensus recommendations from an expert panel might be a good way of developing screening benchmarks.

Further, the closest contemporary approximation of “pristine” conditions would likely be designated wilderness areas. The Wilderness Act of 1964 states that “[a] wilderness is ... recognized as an area where the earth and its community of life are untrammelled or unchanged by man, where man himself is a visitor who does not remain.” If natural conditions were narrowly defined as being limited to wilderness areas where the earth is unchanged by man and man is a visitor who does not remain, then watersheds that had been inhabited for thousands of years by native Americans prior to European-American settlement could not be considered natural. As of 1805, the lower Snake River and Columbia rivers were well peopled with large villages established at about ~20 miles apart, which was about a day’s travel (Lewis and Clark 1997). Hence, prior to Euro-American settlement, the Pacific Northwest could not be considered wilderness using a contemporary definition. To us, “natural” is not intended to reflect such a narrow concept that conditions occurring in the Pacific Northwest prior to extensive Euro-American settlement would not be considered “natural.” Thus in our view, a watershed may be considered “natural” even if it could not be considered “wilderness” or “pristine.”

Natural Variability

A policy of restricting increases in pollutant levels above natural background conditions requires a quantification of natural variability of the pollutants in the water body of interest. This quantification requires information on the conditions of interest and their variations over set periods of time and space. Common metrics used to describe these conditions and their variability include mean, median, percentiles, range, standard deviation, coefficient of variation, frequency, spatial arrangement and size and shape distributions. Range is often used to describe natural variability and to evaluate when current conditions are beyond the bounds. However, when used alone, the range is not appropriate for this purpose, because rare, extreme events define these bounds (Landres et al. 1999). The evaluation of any of these metrics involves comparative methods to other sites or in time. Although the data and metrics used to interpret effects are quite varied (e.g. temperature, substrate characteristics, taxa richness, concentrations) the methods of analysis are quite similar and involve comparison of impact sites with reference sites, or if information is available prior to the potential impact comparison of Before-After-Control-Impact (BACI). Several variations of these statistical methods have been advocated, see for example Underwood (1994), Stewart-Oaten and Bence (2001), and Smith (2002).

Natural variation in stream temperatures on temporal and spatial scales are illustrated in Figures 1 and 2. Spatially, stream temperatures vary with elevation, and on smaller scales cool pools, tributaries or groundwater upwelling, may provide coolwater refuges for fish within otherwise warmer waters. Figure 1 illustrates the plume of cooler water tributary as it mixes with the warmer mainstem river. Temporally, stream temperatures vary on four time scales – within day, day-to-day, within year, and year-to-year. The first four are well known, and are commonly dealt with in water quality regulations by focusing on summertime peak temperatures. In contrast, year-to-year variations are usually ignored in water quality regulations (Essig, *in press*). Examining one site with

nine-years of individual data points for the same summertime periods each year shows that at different times throughout the summer these, year to year differences due solely to natural variation are often $>5^{\circ}\text{C}$ (Figure 2). Figure 3 compares natural variability in various peak temperature metrics for a stream with a 15-year period of record. These too show about a $\pm 5^{\circ}\text{C}$ range in peak temperatures. For example, from 1998 to 1999, maximum daily average temperatures were about 19°C and 23°C . These differences are sufficient to cause a stream to be rated as suitable or unsuitable for coldwater aquatic life communities from year-to-year, or in and out of compliance with regulatory standards.

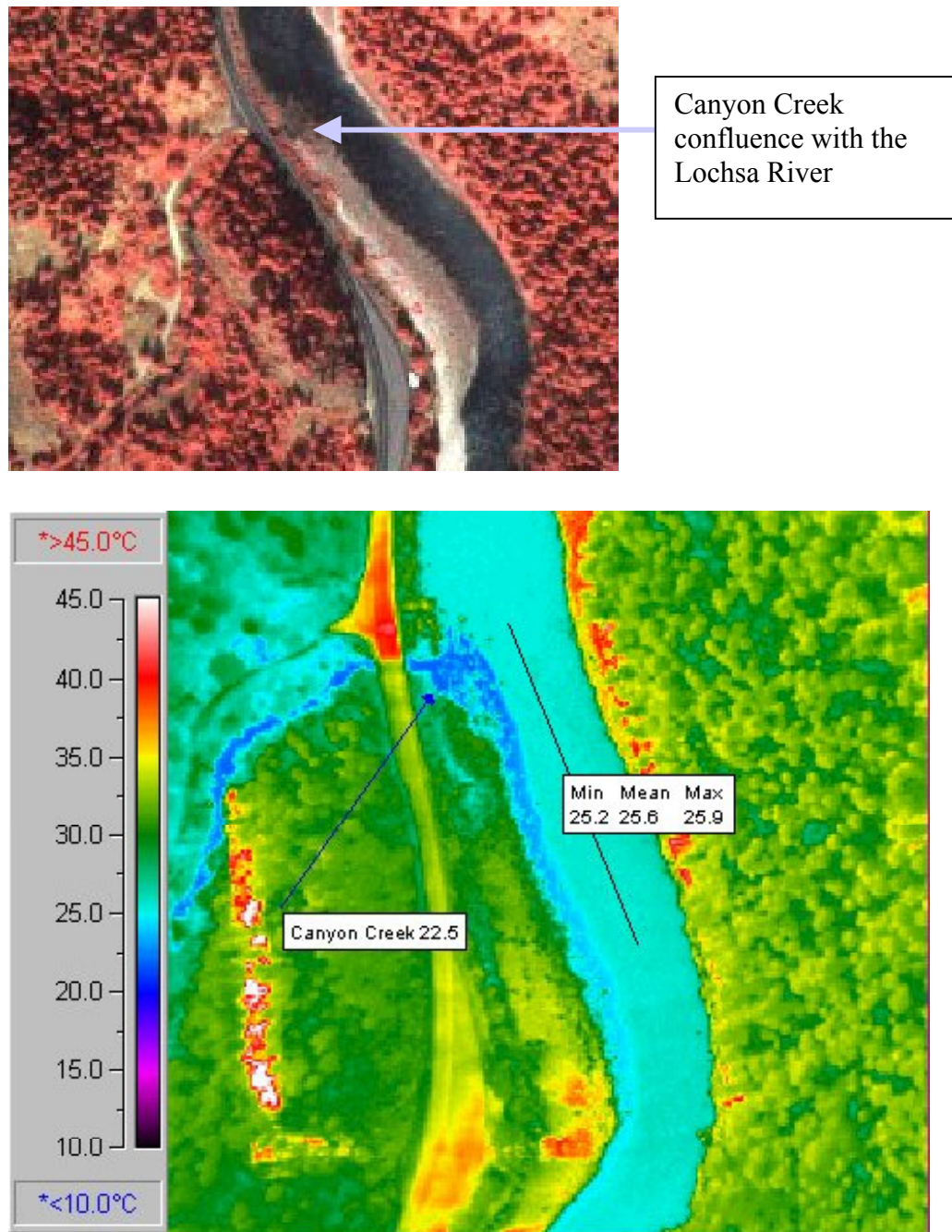


Figure 1. Spatial variability in stream temperatures - cool tributary entering warmer river viewed through paired color infrared and thermal infrared imaging.

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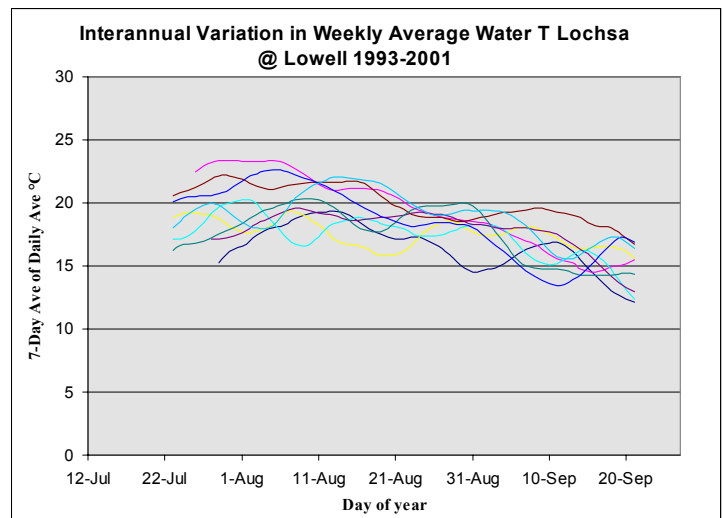
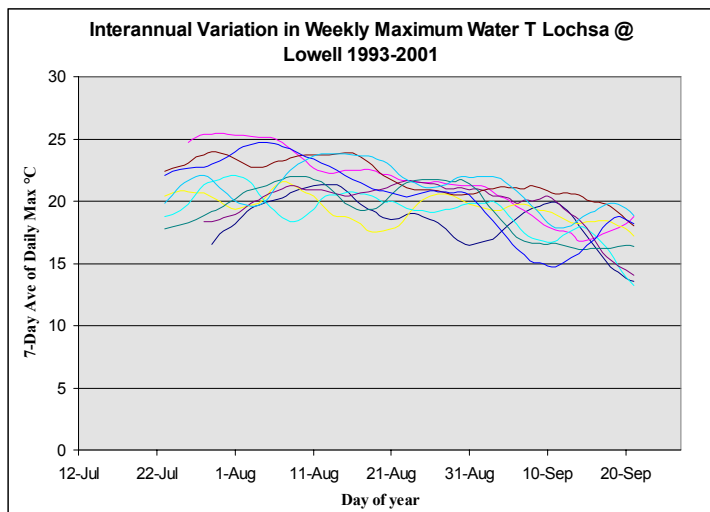
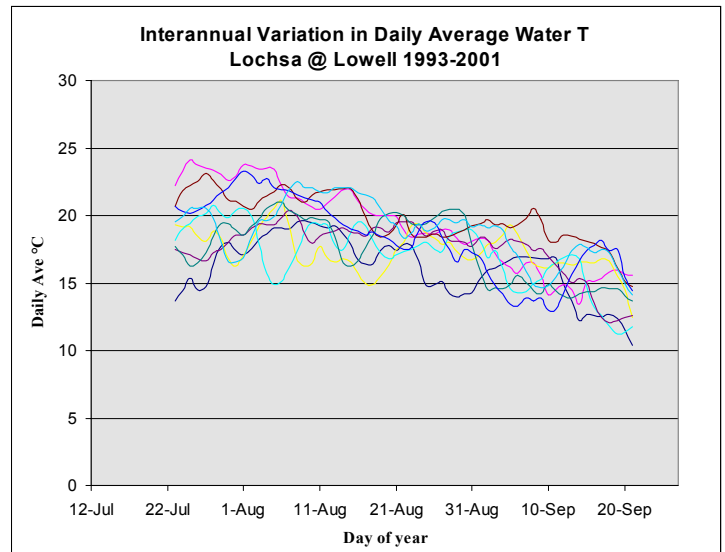
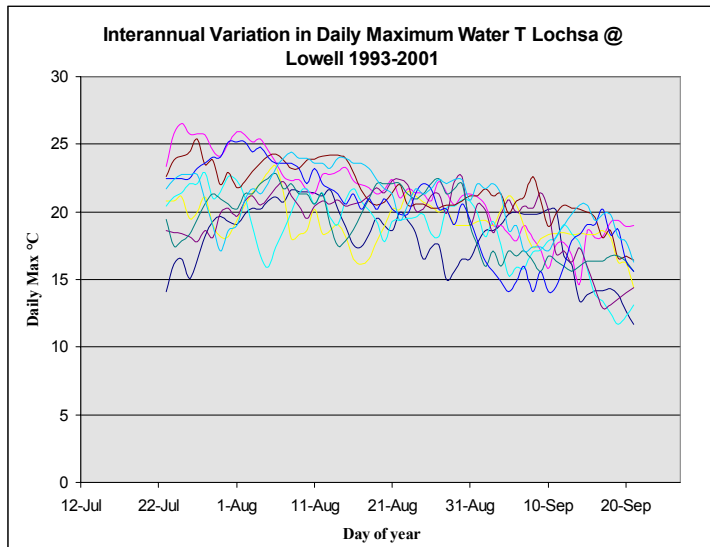


Figure 2. Year-to-year natural variability in daily maximum, daily average, weekly maximum, and weekly average temperatures; Lochsa River 1993-2001 (U.S. Forest Service data)

SITE 13340600 - N. FRK CLEARWATER RVR NR CANYON RANGER STATION

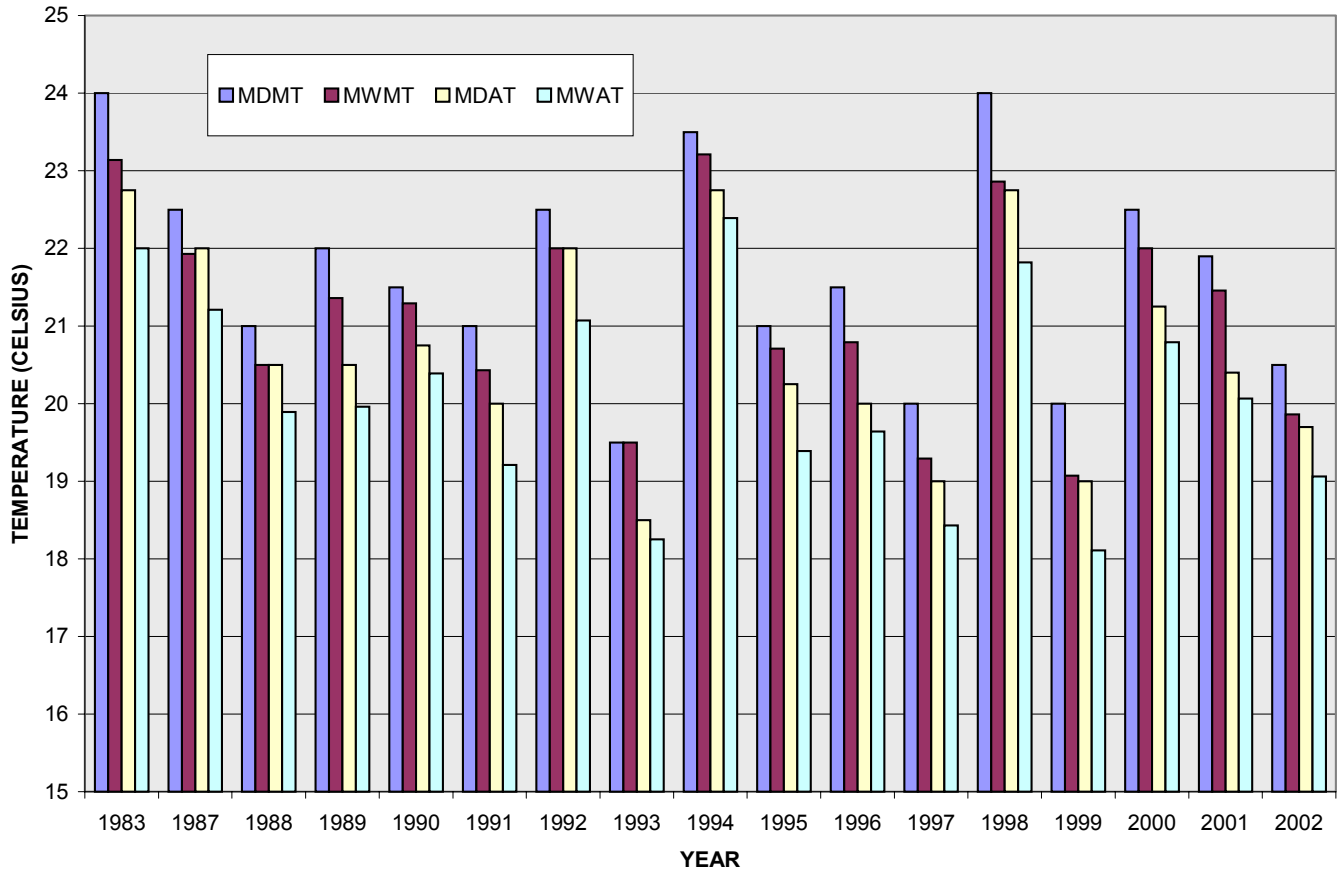


Figure 3. Year-to-year natural variability in peak temperatures: maximum instantaneous (MDMT), maximum weekly average of daily maxima (MWMT), maximum daily average (MDAT), and maximum weekly average (MWAT) temperatures (U.S. Geological Survey data).

Measurable Changes

Factors affecting whether a change is measurable in a water's characteristic such as temperature or a concentration include the detection limits and statistical considerations.

Detection Limits

Any measuring method has some inherent limit of detection that is based on the instrument and the parameter of interest. A limit of detection is the lowest amount of a substance or other parameter that can be reliably detected, based on the variability of either the blank response or that of a low level standard. A related term is the quantitation limit, which is the lowest level at which a substance may be accurately measured and reported without qualification as an estimated value. In chemical analyses, this is often estimated to be 5-times the detection limit (EPA 1991).

Field measurements of water temperature are routinely made by deploying data logging thermistors. Typically these devices display and record values without rounding or truncating to 1/100th of a degree (0.01°C). However, this display of apparent precision can be misleading. These devices are manufactured to be accurate to $\pm 0.2^\circ\text{C}$, based on comparisons to NIST standards (e.g. Onset Computer Corporation www.onsetcomp.com). Temperatures recorded by data loggers are also digitized in discrete steps, the size of the step is determined by the amount of memory allocated to each measurement. For example, data loggers commonly use 8-bits to record a single temperature. Over a devices' range of -4 to $+38^\circ\text{C}$, there are 2^8 or 256 steps, which works out to average quantization errors of 0.16°C.

The repeatability of temperature measurements was further evaluated through a calibration test of the variability of the responses of several data loggers tested together in a bucket at constant temperatures. In this test, 18 units were set in a bucket at room temperature, allowed to equilibrate, and then the temperature measurements by each unit were recorded at 1-minute intervals for 10 minutes. Then the units were moved to an ice bath, allowed to equilibrate, and then the temperatures were recorded. Results were consistent, whether calculated as the ranges of average temperatures, differences of maximum temperatures, or the average of the range of differences recorded for each unit. At room temperature, the units were accurate to $\pm 0.3^\circ\text{C}$ and at freezing (ice bath), accurate to $\pm 0.2^\circ\text{C}$ (Table 1). Since temperature criteria and concerns are usually focused at higher temperatures, not freezing, the room temperature test is the more relevant for estimating the limits of repeatable temperature measurements.

Table 1. Bench tests of temperature measurement error at constant temperatures ($^\circ\text{C}$)

Condition	Grand average Temperature (\pm SD)	Range of average temperatures	Differences in maximum temperatures recorded	Average range of temperature differences	Number of sensors	Measurement interval
Room temperature	21.64 (0.08)	0.28	0.32	0.32	18	1/minute
Ice Bath	-0.01 (0.05)	0.15	0.17	0.18	18	1/minute

The bench test of accuracy of temperature measurements in a static vessel at constant temperatures represents an environment of minimum variability. In practice, temperature comparisons are made in natural streams at fluctuating temperatures. These field conditions introduce additional variability into temperature measurements and comparisons. Temperature loggers are often placed to evaluate nonpoint or point source temperature effects (Zaroban 2000). For example, to assess temperatures relating to nonpoint source watershed disturbances, loggers should be placed at the downstream end of a reach with relatively uniform morphology, land use, and cover. Once in the channel, the logger should be placed in a shaded spot where the water is well mixed and not influenced by warm or cool water sources such as ground water, tributary confluences, or direct sunlight. In flowing waters, well mixed waters normally occur in the center of the thalweg. To show that the water at the site is well mixed and representative of reach conditions, horizontal and vertical mixing is verified with handheld temperature measurements (Zaroban 2000). These protocols for site selection and placement of temperature data loggers in streams minimize confounding field measurement error and improve the comparability of data between places and times. However some added field variability is unavoidable.

Table 2 presents selected results of differences between temperature measurements from two reference sites with six replicate sensors, and 28 sites with duplicate sensors deployed for the same 62 day periods. Each sensor was mounted in a flow-through shading canister and were placed in a well mixed portions of the streams following Zaroban (2000). Sensors were placed at the top and bottom of habitat and biological sampling reaches, about 40-stream channel widths apart, which worked out to 100-200 meters apart. Two sites were replicated to compare variability of physical and biological measurements within what appeared to be representative reaches. Each temperature sensor was considered to be representative of the reach, so differences among these individually representative sensors can be considered to be measurement error. When reduced to conventional regulatory temperature metrics, the maximum daily average temperatures (MDATs) from these site replicates never varied more than to $\pm 0.34^{\circ}\text{C}$. The maximum daily temperature (MDMT) differences were never greater than $\pm 0.65^{\circ}\text{C}$ (Table 2).

Table 2. Differences in commonly used temperature metrics among sites with duplicate or multiple sensors. Each replicate reach (RR) had duplicate sensors, A-upstream end of reach, B-downstream (Source – Ott and Maret 2002)

(a) Replicated sites (3 replicates with 2 sensors each)		MDMT (°C)		MWMT (°C)		MDAT (°C)		MWAT (°C)	
Stream		A	B	A	B	A	B	A	B
Big Creek, RR 1		19.54	19.54	18.44	18.40	13.79	13.79	12.95	12.94
Big Creek, RR 2		19.51	19.64	18.45	18.51	13.87	13.84	13.04	13.00
Big Creek, RR 3		18.99	19.05	17.96	18.08	13.53	13.66	12.70	12.85
Range		0.65		0.55		0.34		0.25	
Valley Creek, RR 1		21.99		20.61		16.03		15.18	
Valley Creek, RR 2		22.18	22.06	20.72	20.67	16.05	16.14	15.21	15.29
Valley Creek, RR 3		22.53	22.19	21.04	20.75	16.29	16.18	15.43	15.33
Range		0.54		0.43		0.26		0.25	
(b) Non-replicated sites (28 sites with 2 sensors each)									
		MDMT (°C)		MWMT (°C)		MDAT (°C)		MWAT (°C)	
Average difference		0.12		0.09		0.07		0.07	
Maximum difference		0.34		0.29		0.23		0.22	

Sites with multiple sensors tended to record slightly higher variability than the sites with just two sensors. Also, averaging reduces variability, with the metric with no averaging being the most variable (MDMT) and the metric with the most averaging (MWAT) having the least variability (differences between MDAT and MWAT were nearly identical).

While some measurements of temperature metrics at field replicate sites varied up to 0.6°C, most differences were 0.3°C or less. From this we conclude that when appropriately deployed (e.g. following Zaroban 2000 or similar protocols), temperature data loggers are nearly as precise for long deployments in fluctuating environments as in bench tests. *From these analyses, we conclude that potentially measurable changes in temperature are differences greater than 0.3°C.* Both the bench tests and the field tests show the remarkable stability and repeatability of properly deployed modern temperature data loggers.

For chemical analyses, at concentration above the quantitation limit quality control guidelines for laboratory duplicate analyses are customarily set at relative percent difference (RPD) of $\pm 20\%$ (EPA 1991, Beltman et al. 1993). However, as concentrations approach the limits of the instrument's capability to "see" the analytes, differences increase. Beltman et al (1993) reported RPD's in field replicates of up to $\pm 50\%$ for dissolved copper at concentrations $<10\times$ the detection limits, but at higher concentrations RPDs were usually less than $\pm 10\%$. Since the issue of a measurable change is in the context of the requirement not to measurably exceed background

conditions when background *exceed* numeric standards, ambient concentrations will likely be sufficiently high that differences of > 10% are at least potentially detectable in laboratory analyses. In contrast, in the case of analyses of waters with concentrations approaching detection limits (and well below numeric standards), variability may be much higher. These types of low-level analyses may be needed for evaluations of special resource waters or nondegradation of high quality waters. Mebane (2000) concluded that in the upper Salmon River, where ambient concentrations were very low, minimum detectable differences for copper and zinc were 2 µg/L and 13 µg/L respectively. In cases like these with low concentrations, a large amount of the data may be below the detection limit which requires special consideration in statistical analyses (Helsel 1990).

Statistical Considerations

Statistics are an inherent part of evaluating changes from background conditions, as well as nearly all water quality monitoring programs. A common question of monitoring programs is whether a particular management action is having an adverse change in water quality. To quantitatively answer this question, it is necessary to acquire data and make statistical comparisons to other site(s), or to data from the site before and after the activity (MacDonald et al. 1991). In the present case of using natural background conditions to manage water quality where “pollutant levels shall not exceed the natural background conditions,” it is necessary to both determine natural conditions and whether they are exceeded. Desirably, once natural conditions are determined, monitoring and assessment to determine whether conditions are exceeded due to an action should likely to detect differences in ambient water quality if in fact they exist (referred to as having a low Type II error in statistical jargon). Further, the assessment should be unlikely to falsely indicate there is a difference when in fact there is none; that is, observed differences are just due to chance (low Type I error). The detection limit becomes an intrinsic part of statistical comparisons, which require selection of a minimum detectable effect.

Statistics are not a “black box” calculations, nor should they be rote. Before statistically examining existing data for changes from background conditions or designing a monitoring program, the investigator must answer certain questions:

Which is the greater concern – falsely concluding that an effect has happened, which could cause unnecessary expense or restrictions to dischargers, land managers, etc. (Type I error), or to fail to detect actual effects which could allow environmental degradation (Type II error)?

How much increase in the parameter being evaluated (e.g. temperature, metals concentration, % fine sediments) is acceptable before concluding that values exceed natural conditions? Although the regulatory answer may be “no increase is acceptable,” this is not a statistically acceptable answer because no monitoring program or statistical test can detect an infinitesimal increase. A minimum detectable effect must be selected (MacDonald et al. 1991).

When working with the requirement for activities to not to exceed background conditions when background *exceed* numeric standards, a fundamental question when evaluating monitoring data is whether a significant change has occurred. The ability to statistically analyze this depends upon compromises between five interacting factors: sample size,

variability, level of significance, power, minimum detectable effect (MacDonald et al. 1991).

1. *Sample size*: Larger sample size increases the ability to detect a difference between two groups of samples.
2. *Variability*: The more variable a measure, the less the ability to detect significant change.
3. *Level of significance*: This refers to the probability that an apparently significant difference is not real but simply due to chance. This is referred to as α or a Type I error. The α value is often arbitrarily set at 0.05 for confirmatory statistical tests and 0.10 in exploratory tests. An α of 0.10 means there is a 1 in 10 chance that an observed difference is due to chance, or a test is 90% “confident.” The lower the significance level is set at, the more likely the difference is real. However, lower significance levels also mean that a test has reduced *power* to detect real differences if they exist.

Significance testing requires choosing between a “one-tailed” or “two-tailed” test. The one-tailed probability is exactly half the value of the two-tailed probability, so for a given test a one-tailed test is more likely to be significant. A two-tailed test is appropriate when the investigator cannot predict the direction of response based on theory, a one-tailed test is appropriate when the investigator can predict the direction of potential response, if any. For example, removal of riparian vegetation would be predicted to result in an increase in summer time stream temperatures, so a one-tailed test would be appropriate; however removal of riparian shade could result in either an increase or decrease in trout populations due to increases in primary productivity and temperature, so a two-tailed test would be appropriate.

4. *Power*: The probability of detecting a difference when in fact one exists; designated $(1-\beta)$. β or a “Type II” error, is the probability of incorrectly concluding that two groups of samples are the same when in fact they are different. In environmental sampling β is commonly set at 0.25 to 0.1; that is a test has a 75% to 90% probability of detecting a change if there is one. While higher probabilities would be desirable, because power function curves are logarithmic, as sample sizes increase, further increases in sample size make little improvement in a test’s power. Tests with 90 to 95% statistical power and α of 0.05 or less would require huge sample sizes. Increasing the statistical power of a sampling plan reduces the likelihood of making a Type II error (failing to detect an actual difference), but at the same time increases the likelihood of making a Type I (concluding there is a difference when none exists). As a starting point for evaluating if activities result in an exceedence of natural background conditions, we suggest power and significance values of $\alpha < 0.1$ and $\beta < 0.2$.
5. *Minimum detectable difference (MDD)*: Determining how much change is acceptable and thus needs to be detected in the ambient concentrations is a key factor in

monitoring. Large differences are easily detected in environmental monitoring; subtle changes are difficult to detect. Therefore, for a monitoring program it is necessary to specify how much change is allowable before a beneficial use is impaired. (MacDonald et al. 1991). As starting points, we suggest using 0.3°C for a minimum detectable difference for temperature and 0.5 standard deviations of the mean for other parameters. Overton et al. (1994), Mebane (2000), and Fore (2003) provide examples of calculating minimum detectable differences for stream habitat parameters, metals concentrations, and macroinvertebrate metrics respectively.

This discussion is intended to point out some key statistical considerations when evaluating whether an activity has resulted in an increase over natural background conditions. It is not intended to be comprehensive. MacDonald et al. (1991); Conquest et al. (1994); and biostatistical texts such as Zar (1984) cover the topic well and give worked examples.

Practical Approaches to Estimating Natural Conditions

The use of natural conditions concepts in water quality management often requires some sort of quantification of natural conditions or variability since natural conditions are not static. For example, Idaho rules require that “when natural background conditions exceed any applicable water quality criteria ... the applicable water quality criteria shall not apply; instead, pollutant levels shall not exceed the natural background conditions.” In order to allow and enforce this provision, some documentation or quantification of the range of natural conditions is needed. The following describes several practical quantitative or semi-quantitative approaches to estimating natural conditions. Because even a consensus definition of “natural conditions” may be elusive, recommendations how to quantify natural conditions will likely also be challenging and subject to debate.

Any application of narrative natural background water quality standard needs to follow a case-specific analysis. It is not feasible to specify in advance all the ways that could be appropriately done, however the following general approaches may be useful. These approaches are not mutually exclusive, and may complement each other, or could be hybridized. Depending upon the complexity of the situation, the question being asked, and the significance of the conclusions, analyses may be simple and qualitative or may need to be rigorously quantitative. *Regardless, some form of analysis is necessary in order to make any statement about natural conditions.*

Natural Watersheds

Watersheds located in designated wilderness, or *de facto* wilderness such as wilderness study areas, roadless, or nearly roadless areas are presumed natural. In these areas, stream characteristics such as water temperatures and sediment loads, are whatever they are. If no new potential nonpoint or point source human-linked pollutant sources are proposed, no quantitation is necessary to determine regulatory compliance with natural conditions. For example, such waters should not be included in listings of water quality limited waters. If a watershed upstream of the location being assessed is roadless, since

most major human-caused disturbances require some sort of road access, there is probably little reason to question its naturalness. However, most watersheds have some discernable human imprint, yet in many cases that human imprint may be insufficient to change the temperatures of the watershed's streams. If absolutist interpretations such as "no human entry" are unreasonable, then how much human disturbance can occur in order to consider a watershed "de facto natural?" Does the sparse network of trails and campsites through the River of No Return Wilderness affect the naturalness of the water quality? What about somewhat greater disturbances such as the sparse network of roads and small urban centers in the Yellowstone National Park drainages? Or a denser network of roads and associated disturbances? At some point, increasing disturbances in a watershed inevitably change the character of water bodies within. However, no definitive and generally applicable thresholds seem apparent. Yet, depending upon the type of aquatic-ecosystem, some general guidelines do seem possible for presuming when a stream is in its natural condition.

The common human-disturbances are different in arid rangeland streams than in mesic forest streams. Water withdrawals and cattle grazing with its associated riparian and streambank changes are common disturbances in rangeland streams. Logging and road construction are common disturbances in forest streams (Omernik and Gallant 1986; McGrath et al. 2001). Further, the riparian habitat and aquatic ecology of rangeland and forest streams are fundamentally different, and they have differing expectations for biological communities (e.g. Grafe 2002). For these reasons, general guidelines for forest and rangeland watersheds are discussed separately. "Rangeland" watersheds include those in the Snake River Plain, Northern Basin and Range, and Columbia Plateau ecoregions; "forest" watersheds include those in the Idaho Batholith, Northern Rockies, and Central Rockies ecoregions (McGrath et al. 2001).

Obviously, careful field evaluations would be preferable to any guidelines presuming natural conditions. However, with about 2500 water body identification units specified in Idaho water quality standards, some prioritization of field investigation is needed. This is the main reason for suggesting guidelines for presuming if stream conditions are "natural." It may bear noting that Idaho water quality standards require waters to support beneficial uses and meet standards, they do not require waters to be "natural." Rather, this discussion of naturalness is only an issue when the waters exceed a water quality standard for natural reasons.

Forest watersheds

As general guidelines, *if*:

1. No forest harvest impinges [riparian areas](#)³; and

³ For this purpose, for fish-bearing streams riparian areas are recommended as consisting of the stream and the area on either side of the stream to the top of the inner gorge, or to the outer edges of the 100-year floodplain, or to the outer edges of riparian vegetation, or to a distance equal to the height of two site-potential trees, or to 300 feet slope distance extending to both sides of the stream channel, whichever is greatest. Tributaries are recommended to have similar definitions except the widths would be less, depending if they were permanent, non-fish bearing streams or intermittent streams. Recommended widths were taken from USFS (1995). Because in this context, intact riparian widths are recommended as one

2. No riparian roads are present and few road crossing exist; and
3. No evidence of sources of sediment delivery that are associated with human disturbance such as gullies originating from culverts, mass failures associated with road fills or timber cuts; and
4. No water withdrawals are present;

then, stream water temperatures may be presumed to be natural.

Watersheds may have apparent human disturbances (such as roads and timber harvest) that do not influence natural stream temperatures, if the disturbances are spatially isolated from the streams. If riparian vegetation is intact and no widening and shallowing of stream channels due to observed sediment delivery is evident, then temperatures may be presumed to be natural.

The use here of the word “presumed,” is deliberate and specific; there could be cases where significant upslope disturbances in a watershed change stream conditions from natural, even if riparian areas are undisturbed. In that case, this presumption could be refuted by evidence. For example, Swanston (1991) and Chamberlin et al. (1991) describe natural watershed processes that influence stream habitats and human activities that can alter them, even if an intact streamside riparian zone is maintained.

Timber harvesting activities within a watershed can affect streamflow by altering the water balance and by affecting the rate at which water moves from hillsides to stream channels. It is well known that a reduction in evapotranspiration, such as due to vegetation removal, results in more streamflow (pg 84 in Hewlett and Nutter, 1969; Troendle and Leaf, 1980). The important questions are at what point does increased streamflow become measurable, and beyond that, at what level of increased streamflow does the channel form respond. Duration and magnitude of annual high flows, rather than overall water yield, are key to stream channel maintenance (Rosgen, 1996, Emmett, 1999). On the other hand, for maximum stream temperature, summer low flows are more critical.

Harvested areas contain wetter soils than unlogged areas during periods of evapotranspiration and may result in higher groundwater levels and more potential late-summer runoff. The effect lasts 3-5 years until new root systems occupy the soil. In contrast, extensive clear-cutting can result in streamflow changes for several decades. Clear-cutting causes increased snow deposition in openings and advances the timing and rate of snowmelt. Snowmelt can be accelerated by the large wind-borne energy inputs of warm rain falling on snow. The minimum cut areas of a watershed associated with hydrologic changes in Chamberlain et al.’s (1991) review were measurable (13%) increases in peak winter storm flows following clearcutting of only 19% of a watershed (although a 13% increase in peak winter storm flows may not result in measurable changes in maximum stream temperatures). In another five studies, the change in water yields in the first year following timber harvests of 35-100% of watershed area ranged

factor in a rebuttable presumption of natural stream conditions, these riparian width recommendations are broad. While narrower riparian widths may in some cases be sufficient for natural stream conditions, that should not be presumed and would need to be demonstrated on a case specific basis.

from negligible to 40%. In a more recent review, Bartholow (2000) concluded that comprehensive reviews of studies of timber harvest effects on water yield suggest that changes in water yield become measurable after about 20% of the catchment area is harvested. One study cited found that timber harvest reduced the number of low-flow days during the summer, including drought years, likely due to reduced evapotranspiration. However, Bartholow concluded that while increases in annual peak flows may result in overall water yield increase with logging, most literature reviewed did not appear to support any significant change to low summer base flows (Bartholow 2000).

Chamberlain's and Bartholow's reviews suggest that an equivalent clearcut area of greater than about 20% of the watershed area in a watershed is potentially significant and stream hydrology could be altered from pre-disturbance conditions and, independent of intact riparian zones, may not be entirely natural. If in cases like this, concerns can be substantiated that effects beyond the [four categories](#) listed at the beginning of this section are influencing physical, biological, or chemical characteristics of the stream, then instead of presuming stream conditions are natural, further analyses should be made, as described in the following sections. However when considering watersheds with light disturbances, mere conjecture that just because effects are conceivable, they therefore should be presumed to be actual, would be unpersuasive to us.

Rangeland Watersheds

Thresholds for *de minimus* human disturbances changing natural conditions for rangeland streams are probably harder to define than for forest streams. Water withdrawals, livestock grazing, and replacement of native riparian plants by invasive exotics are common human-caused disturbances affecting the naturalness of rangeland streams. Water withdrawals tend to increase summer stream temperatures due to lower water velocities and increased residence time. By trampling and overgrazing, cattle grazing can directly affect riparian vegetation, change streambanks and channel morphology, resulting in increased sediment transport and stream temperatures. These changes in sedimentation and temperature in turn can result in biological changes such as reduced salmonid populations and shifts in the stream communities (Platts 1991; Bauer and Burton 1993, Li et al. 1994). Native deep-rooted plant species such as sedges (*Carex* spp.) and rushes (*Juncus* spp.) support grazing animals' weight with little or no damage except under very wet conditions. In contrast, bluegrasses (*Poa* spp.) and bromes (*Bromus* spp.) are shallow-rooted and the hooves of large herbivores are more likely to penetrate the root mass, exposing the roots and soil surrounding the roots to water erosion. Shallow-rooted grasses such as Kentucky bluegrass may be as little as one third as effective as deep-rooted plants such as sedges for protecting streambanks (Cowley 2002). Bluegrasses and bromes have been widely introduced and well established in western North America because they are hardy and have high protein for grazing cattle (Burrill et al. 1992).

Presumptions about "natural" conditions in rangeland streams are complicated by the nature of grazing pressure on riparian zones. Riparian zones have always been grazed by native ungulates, and riparian vegetation has evolved with herbivory. Historically, a riparian zone with the complete exclusion of grazing would not be typical of natural

conditions. For example, during pre-horse times (before the 1500s) in non-drought periods, the Great Plains might have supported an average bison population of 28-30 million (Flores 2001). Thus, at least periodically, significant grazing and trampling was a natural feature of many western watersheds. Osborne Russell described the habitat and wildlife in eastern Idaho, western Wyoming, and southern Montana from 1834 to 1843. His notes are among the most detailed and useful in terms of natural history of the region for the period. In his descriptions of travels through watersheds including the Portneuf, Bear, Malad, Snake, Blackfoot, Willow, Salt, Teton, Henry's Fork, and Yellowstone, Russell often uses terms such as "verdant," "luxuriant" or "thickly clothed with grass" to describe the vegetation in the area for that period. However, he did note a river bottomland where their horses had to eat cottonwood bark "*as the buffaloe have entirely destroyed the grass throughout this part of the country*" (Russell 1955, p. 51).

While some riparian grazing is natural, it does not follow that contemporary livestock grazing is an equivalent disturbance to grazing by deer, elk, and or bison. However, few quantitative studies have examined the differences on streams between grazing by livestock or wildlife (Rinne 1999). For example, when given free choice, cattle might prefer riparian grazing more than their closest natural analogue, the bison. In the 1830s when bison were still numerous in the upper Snake River basin, Russell noted that when both riparian and upland grazing were available, the bison preferred upland grass – "*The buffaloe are very particular in their choice of grass always preferring the short of the uplands to that of the luxuriant growth of the fertile alluvial bottoms. Thus they are taught by nature to choose such food as is most palatable and she has also provided that such as is most palatable is the best suited to their condition....*" (Russell 1955, p. 140).



Figure 4. River-riparian ecosystems have evolved with some degree of grazing. However, concentrated grazing can result in channel alterations, loss of riparian vegetation, and increased stream temperatures. The dark band on the stream bank in the foreground of this photo has no vegetation due to trampling.

The significance of grazing on rangeland stream conditions is more difficult to estimate with landscape analyses than with forest streams. Roads and timber harvest are usually accurately mapped by land managers, and once mapped they usually don't move around much. In contrast, grazing allotments are often large and grazing is usually managed by animal unit months (AUMs). Allotment maps give rough indications of areas subject to grazing but typically give no information on whether actual grazing is dispersed throughout the allotment, or concentrated in the riparian zones. Bauer and Burton (1993) note that in the West, livestock are attracted to riparian areas because of succulent forage, accessibility, shade, a reliable water supply and a microclimate more favorable than the surrounding terrain. Unless livestock are actively managed to avoid riparian areas, through exclusion fencing, providing off-channel water, or active herding as examples, this can result in preferential use of streamside areas compared to the upland rangelands. Recent riparian research has found that moderate-grazing that was managed to meet typical land management agencies' utilization guidelines was little different from areas with no grazing (Clary 1995). Clary and Kinney (2002) evaluated ranges of cattle

grazing effects on streambanks by dropping steel weights to simulate cattle trampling, defoliating vegetation by clipping to 10 cm, and spreading simulate urine and fresh manure on streambanks. They found no differences between the no-grazing and moderate grazing treatments for change in stream width, bank angle, bank retreat, or root biomass. Although the most severe treatment reduced above ground streambank plant biomass by 87%, the retention of substantial plant growth under moderate levels of simulated grazing suggested that careful riparian grazing can result in harvest of riparian forage without severe environmental impacts.

Evaluating whether livestock management has maintained rangeland streams within their natural physical and biological conditions, will probably require careful field assessment in most cases. Only a few guidelines for *presuming* natural conditions of rangeland streams without conducting careful field assessments seem appropriate:

1. No [riparian](#) roads are present and few road crossing exist; and
2. No water withdrawals are present; and
3. No signs are apparent of human-caused, accelerated erosion such as gullies, downcut stream channels, laid back banks, and
4. No riparian livestock grazing has occurred in the last 10-years; or
5. If riparian livestock grazing is allowed to occur, <10% of the streambanks have been altered, and
6. Stubble height or other benchmarks of healthy riparian vegetation do not indicate grazing over-utilization.

The 10-years since riparian livestock grazing suggestion is based on Overton et al.'s (1994) observation that based on measuring differences between grazed, rested, and ungrazed streams, healing from grazing impacts should occur over a period of 5 to 10 years. The <10% streambank alteration benchmark is from Cowley's (2002) evaluation. Cowley (2002) reviewed literature on riparian and streambank alterations and concluded that <30% alteration of potentially stable streambanks was the minimum required to maintain stable conditions. Streams with <10% alteration of potentially stable banks would seem to allow for near optimal recovery of threatened or endangered salmonids such as Chinook salmon, steelhead trout, or bull trout, and would not retard or prevent attainment of riparian management objectives. "Streambank alteration" was considered the direct disturbance of the streambank by *other than* natural forces of water, ice, and debris. Large herbivores (e.g. cattle, sheep, horses, elk, moose, and deer), off-road vehicles and other recreation, and road crossings are examples of causes of streambank alteration. Features that were considered alterations in streambank surveys were soil trampling, where the surface is affect by deep hoof prints; stream channel shape, or bank shearing, reduced bank height; and the vegetation along the stream reach of interest is similar to that of a reference stream reach. When reference areas are not available, the potential amount of late seral, deep-rooted riparian plant communities along the greenline can be used as an estimate of reference conditions (Cowley 2002).

Riparian ecosystem research has established some utilization and stubble height criteria for maintaining healthy riparian vegetation (Clary and Webster 1989, Clary and Leininger 2000, Cowley 2002). While, results vary by the vegetation communities, most

results reviewed were fairly consistent. For example, for an arid, low-elevation watershed in eastern Oregon that was dominated by the grass redtop *Agrostis stolonifera*, a 5 cm residual stubble height was sufficient to maintain riparian vegetation. In contrast, at high-elevation sedge *Carex* spp. sites in Idaho, at least 10 cm stubble height in late summer was needed. Clary and Leininger (2000) recommended at least 10 cm end-of-grazing season residual stubble height for minimal impact riparian grazing management. In some situations, 7 cm or even less stubble height may provide for adequate riparian ecosystem function, particularly when streambanks are dry and stable or possibly at high elevations where vegetation is naturally of low stature. In other situations, 15–20 cm of stubble height may be required to reduce browsing of willows or limit trampling impact to vulnerable streambanks (Clary and Leininger 2000). On a biomass basis, <30% of the current year's growth has been used as a grazing utilization guideline to protect riparian vegetation (Clary and Webster 1989, Clary 1995).

Comparison to Reference Streams

The next simplest approach to estimating natural stream conditions is probably by comparing the variable of interest (e.g. temperature profile) in the stream being evaluated, to that of one or more reference streams. Reference streams need to both 1) have few impacts apparent from human activities, representing the highest level of support (i.e. best available) in the basin, and 2) need to be similar enough to the stream being evaluated that comparisons are reasonable. Generally, a reference stream needs to be a nearby stream with similar major features that affect temperatures (or whatever the variable of interest is), for example elevation, stream size, channel type or similar potential natural vegetation.

Formalized hierarchical classification systems for selecting reference streams have been described and may be helpful, depending upon the situation (e.g. Grafe and Fore 2002, Mebane 2002, see also the assessment unit concept described by Grafe et al. (2002)). In addition to the stream-by-stream watershed comparison approach, physical features of stream channels could be compared to statistical summaries of features of stream channels that represent natural conditions (e.g. Overton et al. 1995, Fore and Bollman 2002). Such comparisons would still need to show that sample reaches are representative of the assessment area and comparisons are reasonable.

Stream Temperature Models

Stream temperature modeling allows comparison of observed stream-temperatures to modeled natural stream temperatures to evaluate how the temperature characteristics of a stream deviate from estimated natural characteristics or whether natural conditions exceed regulatory thresholds that trigger limitations on allowable increases. For the latter purpose in particular, models need not be perfect to be useful.

There are two basic approaches to stream temperature modeling, 1) mechanistic - energy budget approach, and 2) statistical models. Both approaches use the same principles of heat transfer. The first approach, used by many researchers, is an energy balance method based on the physical processes of heat transfer. Models based on this approach are

essentially sophisticated energy accounting systems that keep track of heat input and outflow to describe and predict changes in stream temperature. Stream temperature has been widely studied and the physics of heat transfer is one of the better understood processes in natural watersheds systems. Heat transfer processes involved in controlling stream temperatures include solar radiation, long-wave radiative exchange with sky and vegetation, convection with air, evaporation, conduction to and from the soil and air, and advection from incoming water sources, including ground water (Donato 2002). These mechanistic energy budget models allow investigators to “remove” quantifiable human influences on temperature, evaluate their significance, and if significant, to allocate reductions.

HDR (2002) illustrates the use of energy budget modeling to analyze how much stream temperatures in a forested watershed vary from natural, and to predict how much stream temperatures could feasibly be lowered by removing human influences. Modeling was initially used to simulate historic daily average and maximum temperatures in the river and tributaries based on historical data, and to evaluate the differences in river temperatures between current conditions and if 100% of river banks were shaded by mature trees (full potential canopy). Modeling was then used to answer the more sophisticated question “what fraction of the departure between current canopy conditions and full potential canopy in the riparian zone is due to natural disturbances, and what fraction is due to human disturbances?” The question was investigated by quantifying the difference in riparian canopy conditions for stands of trees that are undisturbed or have natural changes and those that have human caused changes.

WWA and BA (2002) prepared a case study using energy budget modeling to describe natural thermal conditions in the Chiwawa River, Washington watershed. The Chiwawa was used as a test case to evaluate the practicality of using the natural thermal potential of a river as a regulatory temperature criterion. The concept tested in WWA and BA (2002) was to use the natural thermal capability of the river in lieu of, or in conjunction with more traditional temperature criteria approaches that are based on biological requirements of resident species. The Chiwawa watershed was considered generally representative of forested watersheds in Idaho, Oregon, and Washington that have anadromous salmon and bull trout populations. For the Chiwawa, natural thermal potential was best estimated through modeling that was calibrated to the extensive thermal data recently gathered within the basin. In this approach, condition of stream channels, groundwater, surface streamflows, meteorologic conditions, and shade must be addressed.

The second fundamental approach to stream temperature modeling is to utilize observed statistical relationships between stream temperatures and landscape, climate, vegetation, and stream-channel characteristics to develop empirical models to predict stream temperatures. Donato (2002) developed a statistical model to estimate the natural temperature potential of a wide variety of streams and rivers in the Salmon and Clearwater basins in Idaho. The model takes into account seasonal temperature fluctuations, site elevation, total drainage area, average subbasin slope, and the deviation of daily average air temperature from a 30-year normal daily average air temperature. Many other variables were evaluated but were not significant in her model.

Artificial neural networks (ANN) are another empirical approach that has been successfully used to simulate natural streams temperatures. An artificial neural network

model is a flexible mathematical structure capable of describing complex nonlinear relations between input and output data sets. Risley et al. (2002) used the ANN approach to estimate water temperatures in small streams in western Oregon having undisturbed or minimally disturbed conditions. Critical input variables included riparian shade, site elevation, and percentage of forested area of the basin. Model users must assemble riparian habitat and basin landscape characteristics data, which in addition to meteorological data, are model inputs for a site of interest (Risley et al. 2002). The western Oregon model was developed to help determine whether maximum stream temperatures at a site of interest were higher than expected for minimally disturbed sites. The model of natural stream temperatures is part of effort by the Oregon Watershed Enhancement Board to evaluate a method to assess whether a stream is considered “healthy.”

Dyar and Alhadeff (1997), Sudgden et al. (1998), and Sullivan et al. (1990) are additional examples of empirical stream temperature models. Empirically based models may allow broadscale analyses of temperature patterns, or may provide a basis to screen temperature records to estimate whether they are similar to expected temperatures for natural streams. Limitations of empirical models are that they are most reliable when applied within the area for which they were developed, and so are less reliable elsewhere.

Energy balance models such as SNTMP/SSTEMP (Theurer et al. 1984, Bartholow 1999), Heat Source (ODEQ 1999), CE-QUAL-W2 (Cole and Buchak 1995), Mike-11 (<http://www.dhisoftware.com>), and RBM10 (Yearsley et al. 2001) were developed to help aquatic biologists and engineers predict the consequences of stream manipulation on water temperatures. Typical applications include assessing the effects of habitat improvement projects or predicting the consequences of stream manipulation on water temperatures. Limitations of energy balance models are that they usually require extensive data inputs and sometimes incomplete accounting of heat transfer due to poorly understood processes like hyporheic exchange. The accuracy of their predictions is often more limited by available input data than the reliability of their energy accounting. Because of the labor and data requirements, energy balance models are usually impractical for broadscale application, or to screen large numbers of streams for deviation from estimated natural conditions.

Large River Basins

Large river drainages ($>5^{\text{th}}$ order) may be too complicated to easily model natural temperatures (or any other variable), and may have extensive human alterations. In these cases options to evaluate natural temperatures may be limited. These may include 1) comparisons of current conditions to the least-disturbed conditions for which historical records are available (e.g. for dammed rivers, post European settlement, but pre-dam conditions, 2) comparisons to some contemporary least-disturbed reference river, or 3) mass balance accounting of all identifiable anthropogenic thermal changes. Mass balance accounting removes all identifiable thermal changes and attributes the remainder to natural conditions. These approaches require a thoughtful consideration of natural river thermal dynamics, limitations and strengths of possible approaches, and a careful review and analysis of available data. Examples of estimates of natural thermal conditions on

large, extensively altered river basins include Essig (2002), IDEQ and ODEQ (2001), Yearsley et al. (2001), and Cope (2001). Analyses of large, extensively altered river basins have sometimes been referred to as “site potential” to acknowledge that true natural background conditions are unknowable, because of the complexity of the large tributary systems, and or the extent of alterations.

Biological Assessment

Balanced Indigenous Populations in Large Rivers

Under the Clean Water Act, the release of heated water into rivers or other water bodies is treated differently from other pollutants. Section 316(a) of the Clean Water Act prohibits the release of heated water in amounts that would cause adverse effects on aquatic life. The normative standard that is used to judge harm is based on the requirement for protection of a balanced indigenous population. The standard has been interpreted as a balanced community of mostly native species. This concept is in agreement with the primary goal of the Clean Water Act which is to restore and maintain biological integrity (Coutant 2000, Dufour et al. 2003). This narrative standard which does not limit the heated discharges to a specific temperature is in contrast to the approach used for other pollutants in discharges, such as ammonia or bacteria, which are limited to specific numeric criteria. Idaho water quality standards do not presently distinguish heated discharges from other discharges as does the Clean Water Act. However, the concept of protecting balanced indigenous populations is similar and relevant to the concept of protecting natural conditions. Approaches used in other states to evaluate if balanced indigenous populations are protected may be informative with provisions of Idaho’s present water quality standards such as defining expected natural biological conditions or determining whether a measurable adverse change in a biological parameter has occurred which would result in “lower water quality.”

Using an index of biotic integrity (IBI) multimetric index approach, fish and macroinvertebrate metrics assemblages could measure impacts downstream of heated discharges from power plants. Dufour et al. (2003) observed that the degree of impact varied in specific metrics that recognized shifts in assemblage structure and function. Metric declines were particularly evident in warm conditions during late summer (Dufour et al. 2003). This supports the use of biocriteria⁴ in evaluating thermal discharges.

“Healthy” streams and rivers

In streams and rivers of the Pacific Northwest, shifts in fish and macroinvertebrate assemblages have been linked with human disturbances. Fish and macroinvertebrate assemblages have been described for least-disturbed reference sites and quantitative indexes developed to measure departure from those reference conditions. Some evaluations have specifically addressed biological changes associated with temperature

⁴ “Biocriteria” is a term widely used in biomonitoring literature. It refers to developing numerical values that describe the reference biological condition of aquatic communities inhabiting waters. Biocriteria are benchmarks for water quality evaluations, however, they are not *regulatory* criteria as used here.

shifts, both natural and human caused (e.g. Ott and Maret 2003; Mebane et al. 2003). These and other biological assessment tools support development of evaluations methods that rely less on physical characteristics such as variable temperature metrics by more direct biological measures. In addition to research in Idaho and many other parts of North America to develop quantitative biocriteria methods, the Oregon Watershed Enhancement Board is evaluating similar methods to assess whether a stream is considered “healthy.” The following quote describing their investigations was one of the more succinct descriptions of the “stream health” approach found:

“This method compares the biological assemblage in a stream to similar reference sites that are minimally affected by human activities. The concept is called the ‘Healthy Stream Standard.’ It is more of a site-specific evaluation of a stream that relies less on universally applied chemical and physical standards for water quality (such as dissolved oxygen, dissolved solids, and toxins) and more on letting the stream biology tell the story. If the biological population in a stream is appropriate for that ecoregion (in terms of density, diversity, and abundance of stress-intolerant species), then the stream will not be targeted for remediation under the TMDL provision of the Clean Water Act. This proposed Healthy Stream Standard recognizes the fact that some streams can be healthy even if its chemical and physical characteristics do not meet existing standards. It also recognizes that when a stream is not biologically healthy, site specific information is needed in order to assess remediation needs. One of the most critical pieces of site specific information is an estimate of maximum water temperature that would be expected at a site given ‘background’ or ‘undisturbed’ conditions” (USGS 1999).

Lakes

Because of their large surface area, temperatures in lakes cannot be significantly altered by changes in shading from littoral trees, as is the case with streams and rivers. Temperatures in lakes will be presumed to be natural, unless temperatures are measurably anthropogenically influenced. Assume for example, riparian roads result in anthropogenically elevated tributary temperatures due to loss of stream shade. If those tributary temperatures exceed lake epilimnion temperatures, then the surface of the lake will be further elevated.

NPDES permits for heated-effluent discharges to lakes may not be allowed to measurably change the temperature of the lake, beyond that allowed in and at the edge of a mixing zone. Temperatures may be increased up to 1°C at the edge of a mixing zone for lakes designated for cold water or seasonal cold water aquatic life. The areal extent of mixing zones in lakes is not specifically defined; mixing zones should be as small as feasible and must not impair the overall integrity of the water body. For example, if mixing zones in lakes for heated effluents were restricted to the extent of the near-field region of discharge entrained mixing of the effluents with lake water, overall heating of the lake would be minimal. The 1°C limit will prevent maximum temperatures from harming aquatic life, and to prevent localized algae blooms.

Reservoirs with a mean detention time greater than 15 days are considered to be “lakes” for natural background temperature purposes (WQS § 250.02.c). This was based on example language in 40 CFR 131.35 for nearby, similar situations and is supported by EPA (2000) in which “lakes” were defined as natural and artificial impoundments with a surface area greater than 10 acres and a mean water residence time of 14 or more days. This distinction between when an impounded pool on a river becomes a “lake” was based on studies of phytoplankton accumulation in water bodies of different retention times (EPA 2000, citing Kimmel et al. 1990). Small ponds and marshes with little water exchange will warm up to near equilibrium with meteorological conditions.

Metals

Metals in discharges or runoff need to be evaluated in the context of natural background metals in the area. While dissolved metal concentrations away from the immediate influence of discharges are typically lower than surface water criteria, ambient metals concentrations in water resulting from natural weathering and leaching of mineralized areas may be above national criteria levels. However, the natural background geochemistry may be obscured by the overprint of the mining activities. Natural background concentrations in mineralized districts need to be characterized to help devise realistic plans for remediation and monitoring. Three methods are generally described for estimating natural background geochemistry of water in mineralized areas that have been mined: examination of historical documents, comparison to natural concentrations in undisturbed, similarly mineralized areas, and predictive theoretical geochemical modeling (Runnells et al. 1992, Maest et al. 1999).

Since the geologic sources of natural metals will likely be much less variable than say, meteorological conditions, natural background conditions for dissolved metals are probably much less variable than stream temperatures. It follows that if natural background concentrations of metals regularly exceed criteria, establishing site-specific criteria for metals based upon the statistical distribution of values will probably be feasible, and may be desirable for regulatory reasons (e.g. NPDES permitting). For example, if through one of the three approaches described, median natural selenium concentrations for a stream were 20 µg/L, with maximum and minimum reported values of 10 and 40 µg/L, a site-specific criteria could require that no more than 50% of samples may exceed 20 µg/L, and effluent limits and monitoring could be calculated accordingly. If the site-specific criteria were set at the maximum naturally occurring value, the criteria would have to require all samples were lower than the maximum value. However, this would be statically infeasible. The true maximum value of a population of data can never be known from samples of that population; the only way to find the true maximum value in a population is to census every data point, which is usually an impossibility with environmental data. In contrast, central tendency values (e.g. median or a mean value) are a more robust statistic.

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Appendix – Excerpts from Idaho Water Quality Standards relevant to Natural Background Conditions

(As of March 15, 2002)

003. Definitions

003.42. Full Protection, Full Support, Or Full Maintenance Of Designated Beneficial Uses Of Water. Compliance with those levels of water quality criteria listed in Sections 200, 210, 250, 251, 252, 253, and 275 (if applicable) or where no major biological group such as fish, macroinvertebrates, or algae has been modified by human activities significantly beyond the natural range of the reference streams or conditions approved by the Director in consultation with the appropriate basin advisory group.

003.58. Lower Water Quality. A measurable adverse change in a chemical, physical, or biological parameter of water relevant to a beneficial use, and which can be expressed numerically. Measurable change is determined by a statistically significant difference between sample means using standard methods for analysis and statistical interpretation appropriate to the parameter. Statistical significance is defined as the ninety-five percent (95%) confidence limit when significance is not otherwise defined for the parameter in standard methods or practices.

003.65. Natural Background Conditions. No measurable change in the physical, chemical, biological, or radiological conditions existing in a water body without human sources of pollution within the watershed.

003.89. Reference Stream Or Condition. A water body which represents the minimum conditions necessary to fully support the applicable designated beneficial uses as further specified in these rules, or natural conditions with few impacts from human activities and which are representative of the highest level of support attainable in the basin. In highly mineralized areas or in the absence of such reference streams or water bodies, the Director, in consultation with the basin advisory group and the technical advisors to it, may define appropriate hypothetical reference conditions or may use monitoring data specific to the site in question to determine conditions in which the beneficial uses are fully supported.

003.119. Water Pollution. Any alteration of the physical, thermal, chemical, biological, or radioactive properties of any waters of the state, or the discharge of any pollutant into the waters of the state, which will or is likely to create a nuisance or to render such waters harmful, detrimental or injurious to public health, safety or welfare, or to fish and wildlife, or to domestic, commercial, industrial, recreational, aesthetic, or other beneficial uses.

003.123. Watershed. The land area from which water flows into a stream or other body of water which drains the area.

051. Antidegradation Policy.

01. Maintenance Of Existing Uses For All Waters. The existing in stream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

02. High Quality Waters. Where the quality of the waters exceeds levels necessary to support propagation of fish, shellfish and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the Department finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the Department's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing

such degradation or lower water quality, the Department shall assure water quality adequate to protect existing uses fully. Further, the Department shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and cost-effective and reasonable best management practices for nonpoint source control. In providing such assurance, the Department may enter together into an agreement with other state of Idaho or federal agencies in accordance with Sections 67-2326 through 67-2333, Idaho Code.

03. Outstanding Resource Waters. Where high quality waters constitute an outstanding national resource, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected from the impacts of point and nonpoint source activities.

053. BENEFICIAL USE SUPPORT STATUS.

In determining whether a water body fully supports designated and existing beneficial uses, the Department shall determine whether all of the applicable water quality standards are being achieved, including any criteria developed pursuant to these rules, and whether a healthy, balanced biological community is present. The Department shall utilize biological and aquatic habitat parameters listed below and in the current version of the “Water Body Assessment Guidance”, as published by the Idaho Department of Environmental Quality, as a guide to assist in the assessment of beneficial use status. Revisions to this guidance will be made after notice and an opportunity for public comment. These parameters are not to be considered or treated as individual water quality criteria or otherwise interpreted or applied as water quality standards.

053.01. Aquatic Habitat Parameters. These parameters may include, but are not limited to, stream width, stream depth, stream shade, measurements of sediment impacts, bank stability, water flows, and other physical characteristics of the stream that affect habitat for fish, macroinvertebrates or other aquatic life; and

053.02. Biological Parameters. These parameters may include, but are not limited to, evaluation of aquatic macroinvertebrates including Ephemeroptera, Plecoptera and Trichoptera (EPT), Hilsenhoff Biotic Index, measures of functional feeding groups, and the variety and number of fish or other aquatic life to determine biological community diversity and functionality.

53.03. Natural Conditions. There is no impairment of beneficial uses or violation of water quality standards where natural background conditions exceed any applicable water quality criteria as determined by the Department, and such natural background conditions shall not, alone, be the basis for placing a water body on the list of water quality limited water bodies described in Section 054.

200. GENERAL SURFACE WATER QUALITY CRITERIA.

The following general water quality criteria apply to all surface waters of the state, in addition to the water quality criteria set forth for specifically designated waters.

200.09. Natural Background Conditions. When natural background conditions exceed any applicable water quality criteria set forth in Sections 210, 250, 251, 252, or 253, the applicable water quality criteria shall not apply; instead, pollutant levels shall not exceed the natural background conditions, except that temperature levels may be increased above natural background conditions when allowed under Section 401.

250. SURFACE WATER QUALITY CRITERIA FOR AQUATIC LIFE USE DESIGNATIONS

250.01. General Criteria. The following criteria apply to all aquatic life use designations. Surface waters are not to vary from the following characteristics due to human activities:

c. Temperature in lakes shall have no measurable change from natural background conditions. Reservoirs with mean detention times of greater than fifteen (15) days are considered lakes for this purpose

09. Natural Background Conditions. When natural background conditions exceed any applicable water quality criteria set forth in Sections 210, 250, 251, 252, or 253, the applicable water quality criteria shall not apply; instead, pollutant levels shall not exceed the natural background conditions, except that temperature levels may be increased above natural background conditions when allowed under Section 401.

The following criteria apply to all aquatic life use designations. Surface waters are not to vary from the following characteristics due to human activities:

02. Cold Water. Waters designated for cold water aquatic life are not to vary from the following characteristics due to human activities:

c. Temperature in lakes shall have no measurable change from natural background conditions. Reservoirs with mean detention times of greater than fifteen (15) days are considered lakes for this purpose.

v. If temperature criteria for the designated aquatic life use are exceeded in the receiving waters upstream of the discharge due to natural background conditions, then Subsections 401.03.a.iii. and 401.03.a.iv. do not apply and instead wastewater must not raise the receiving water temperatures by more than three tenths (0.3) degrees C.

401. POINT SOURCE WASTEWATER TREATMENT REQUIREMENTS.

03. Treatment Requirements. Unless more stringent limitations are necessary to meet the applicable requirements of Sections 200 through 300 or unless specific exemptions are made pursuant to Subsection 080.02 or 401.05, wastewaters discharged into surface waters of the state must have the following characteristics:

401.03.a. Temperature - the wastewater must not affect the receiving water outside the mixing zone so that:

401.03.a.i. The temperature of the receiving water or of downstream waters will interfere with designated beneficial uses

401.03.a.ii. Daily and seasonal temperature cycles characteristic of the water body are not maintained.

401.03.a.iii. If the water is designated for warm water aquatic life, the induced variation is more than plus two (+2) degrees C.

401.03.a.iv. If the water is designated for cold water aquatic life, seasonal cold water aquatic life, or salmonid spawning, the induced variation is more than plus one (+1) degree C.

401.03.a.v. If temperature criteria for the designated aquatic life use are exceeded in the receiving waters upstream of the discharge due to natural background conditions, then Subsections 401.03.a.iii. and 401.03.a.iv. do not apply and instead wastewater must not raise the receiving water temperatures by more than three tenths (0.3) degrees C.